

TOBACCO MOSAIC

and its control



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Contents

Introduction	3
Symptoms of Mosaic	4
Cause of Mosaic	5
Damage from Mosaic	7
New Methods of Study	7
Principles of Control	8
Sources of Infection	10
Infested Soils	10
Cured Tobacco Refuse	13
Through the Use of Tobacco	14
Other Susceptible Plants	16
Field Infection from the Seed-bed	17
Spread in the Field	19
Mosaic-resistant Varieties	21
Summary of Control Measures	21

Tobacco Mosaic

and its control

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TEN YEARS AGO the control of ordinary tobacco mosaic appeared to be quite hopeless. Investigations since that time have disproved many old beliefs, and established new facts which now make it possible to control this disease. The details of these experiments have been published elsewhere, but the results of most practical interest are summarized in this bulletin.

Mosaic is the most widely distributed disease of tobacco, and in some years is the most serious disease of this crop. All tobacco growers are familiar with it, though it is sometimes known by other names. Some growers do not regard the disease as important, either because it occurs only in small amounts, or because the plants become infected so late in the season that the yield and quality of the crop as a whole are not greatly affected. It receives serious attention only when a large percentage of the plants fail to make a normal rate of growth or when the crop becomes badly "rusty" as a secondary consequence of the infection. It is then too late to attempt any worthwhile control measures for the season, but plans should be made to prevent the recurrence of the disease the following season.

The prevention of the disease is sometimes not easily or conveniently accomplished, but on the other hand control measures do not involve any appreciable expenditure of time or money. It is chiefly important that the growers understand the disease, the sources of infection, and the manner in which it spreads, and then give attention to such preventive measures as may apply to the particular situation.

* In cooperation with the Division of Tobacco and Plant Nutrition, Bureau of Plant Industry, United States Department of Agriculture.



Fig. 1—MOSAIC GETS ITS NAME FROM THE VARIOUS SHADES OF GREEN AND YELLOW COLOR SCATTERED IN IRREGULAR SHAPES OVER THE LEAF
This type of symptom is known as mottling.

Symptoms of Mosaic

LATE SYMPTOMS of mosaic on the young leaves of the plant are easily recognized by the characteristic mottling of the leaves. The very early symptoms of the disease, and also late infections on old leaves may be difficult to distinguish from some normal conditions of the plant, or from certain other abnormalities on tobacco. "Frenching" or "shoe-string", and potash starvation for instance, are sometimes mistaken for mosaic. Occasionally also, tobacco may be affected by another kind of mosaic disease, such as cucumber mosaic, which closely resembles ordinary tobacco mosaic in symptoms, but requires different control measures. Fortunately this latter complication is comparatively rare and needs only brief consideration in the present connection.

The most typical symptom of mosaic is leaf mottling, that is, irregularly alternating areas of light green or yellowish and normal or dark green colors, as compared with a uniform leaf color. It is from this irregular light and dark pattern that the disease received the name of "mosaic" (Fig. 1). Generally young infected leaves become more or less malformed and stunted in growth (Fig. 2). Plants infected when young may make comparatively little growth throughout the season. Infected old leaves may show no mottling or malformation, though they may tend to yellow in large areas or to develop small dead spots or large dead blotches ("rust") (Figs. 3 and 4). Often the grower does not associate this more damaging form of the disease with the mottle form of mosaic because "rust" may also result from other causes. The mottling on the new growth and especially the suckers, however, usually confirms the questionable diagnosis of "rust" due to mosaic.

Cause of Mosaic

MOST OF THE DISEASES of plants are caused by "germs" of known size and form. The agent which causes mosaic behaves like a germ in that it is infectious, but little is known about its size and form because it is too small to be seen under the highest power of the microscope.

The causative agent of mosaic is therefore commonly referred to as a "virus." This virus differs from most germs in that it multiplies only in living tissue, though like most germs it may survive in dead tissue such as dry leaves. The virus spreads throughout the entire plant, usually without killing the tissue and sometimes without showing any striking symptoms; whereas germs more often kill the area infected.

In this connection it is important to know that the tobacco mosaic virus spreads into the root system of affected plants and through the stalks and seed pods, although no conspicuous symptoms may be present on these parts. Fortunately, however, the virus does not pass into the seed itself; consequently seed from mosaic plants does not directly transmit the disease to the plants grown therefrom.

The mosaic disease must in any case arise either from living plants or from dead plant material that has been infected with the disease. It should be noted that certain other, usually related plants, especially tomatoes, may be infected with the same virus and that occasionally the disease may arise in tobacco from such a source of infection. If these facts are borne



Fig. 2—MALFORMATION OF THE LEAVES IS A COMMON SIGN OF MOSAIC

in mind, the frequent mysterious appearance of the disease may be readily explained.

Damage from Mosaic

THE MOSAIC disease may reduce the total yield (Fig. 5) and quality of a crop in widely varying amounts sometimes not easily seen or estimated in the cured leaf. The percentage of plants infected, the time of infection, the weather conditions, and the potential quality of the crop are the chief factors determining the actual loss. The extent to which this loss varies with the time of infection may be readily shown experimentally and has been found to amount to as much as 60% (Fig. 6). However, where no more than 10% of the plants are infected up to time of topping and less than 25% after topping, the actual financial loss may be less than 5%, a loss which is easily overlooked by the average grower. It is only when 20% or more of a potentially good crop is affected before topping and as much as 50% before harvest, and when the disease is accompanied by excessive "rusting" of the weakened plants as a consequence of certain weather conditions, that the grower becomes seriously concerned about preventing recurrence of the disease the following year. It is estimated that the disease reaches these proportions on the average in only about 5% of the fields, though it may cause appreciable losses in 30% of the acreage in the state.

New Methods of Study

MUCH OF THE information recently secured on tobacco mosaic control is based on the so-called "local-lesion" method of determining the amount of virus present in the material tested. When an ordinary tobacco plant is inoculated with the virus, the result is about the same whether one particle or a million particles of virus are introduced into one plant. Naturally the chances for accidental infection in nature are considerably greater where large amounts of virus are present. Hence it is important to know something of the concentration of virus present in the probable sources of infection.

On certain plants, such as a hybrid (*Nicotiana tabacum* x *N. glutinosa*) used especially for this purpose, the virus produces local lesions or dead spots when an extract containing the virus is gently wiped over the surface of the leaf. The number of spots produced represents for practical purposes the number of virus particles in the extract tested. Thus if a small piece of dead tobacco root, for example, is crushed and extracted with a

small amount of water, which is then wiped on a leaf of the test plant, small dead-spots will develop in three to four days if any living virus is present (Fig. 7). The number of spots resulting gives a good measure of the amount or concentration of virus in the extract tested. By this method the presence of as little as one particle of virus in a million parts of extract may be detected.

In this way the amount of virus has been determined in various materials, such as commercial brands of tobacco, tobacco refuse, and tobacco soils. Similarly, by storing such materials under different conditions and testing them after different intervals of time, it has been possible to study the factors concerned in the preservation and in the destruction of the virus, as well as the rate at which the virus is destroyed or inactivated under different conditions. Information thus gained has been very useful in studying the behavior of the mosaic virus under field conditions and in locating the most likely sources of infection.

It is the unusual properties and characteristics of the virus, and its peculiar behavior under certain environmental conditions, which has made the development of mosaic seem mysterious. It has sometimes been quite as much a problem to explain the failure of the disease to develop as to explain its sudden and unexpected appearance. The new methods of study have largely dispelled the mystery of the tobacco mosaic problem.

Principles of Control

THE TOBACCO mosaic virus possesses certain characteristics which enable it to become one of the most common and widely distributed plant diseases in the world. The most significant of these properties is its ability to survive in dry, dead plant tissues for many years, and even to survive in moist soil for as long as two years. Also, the virus is relatively very resistant to heat, since it requires about 200° F. for ten minutes to definitely destroy it, and it may in part survive 180° F. for as long as 24 hours, and thus may partly withstand many curing, processing, and manufacturing treatments applied to certain types and forms of tobacco. Thirdly, the virus is very infectious; even extremely small amounts may start the disease immediately, and its development requires no particularly favorable weather conditions for infection nor for the progress of the disease. Infection may take place merely through broken leaf-hairs in contact with the virus. Plants touched with virus-contaminated hands may hence become infected. On the other hand, infection apparently does not occur through the roots themselves growing in contaminated soil, though



Fig. 3—THE QUALITY OF LEAF-TOBACCO IS GREATLY REDUCED BY MOSAIC
Leaf-spots, large yellowed areas, and drying up of the entire leaf may occur. This type of symptom is often called "rust".

it may take place through leaves or stems placed below the soil surface, as in transplanting. Fortunately, certain types of spread and infection, such as through the air, common to many other plant diseases caused by germs do not exist with tobacco mosaic, and to that extent at least control is simplified. Once a plant is infected with the virus, neither weather conditions nor the application of any sort of treatment will check the course of the disease in the plant.

The principles of the control of mosaic are consequently based on the prevention of infection in the seed beds and in the field. The only means of prevention is the eradication of possible sources of infection, which are discussed in the following section. Absolute control of the disease may not easily nor often be obtained, and may not be necessary, but epidemics of the disease can and should be prevented. The methods of control do not apply equally to all situations, and intelligent observation based on some knowledge of the disease is essential to securing efficient control with the least effort.

Sources of Infection

THE POSSIBLE sources of infection for ordinary tobacco mosaic may be grouped as follows in the approximate order of their importance in Wisconsin: (1) infested soil, including crop refuse, that is, the parts of the tobacco crop that remain in the field; (2) refuse from the cured leaf-tobacco, including stems and trash from warehouses; (3) used tobacco, including manufactured tobacco, cigars, and leaf-tobacco; (4) other susceptible plants, such as tomato, pepper and ground cherry. Manifestly, these sources may vary considerably in importance under different circumstances, and it is only through an understanding of the problem that the information available may be applied most satisfactorily.

Infested Soils

That the tobacco mosaic virus lives over in the soil from one growing season to the next has been proved in different ways. In a practical way it has been shown repeatedly by field records that high percentages of mosaic normally develop in soils known to be infested as compared with uninfested soils when both are planted with healthy plants from the same seed bed.

It is not uncommon to find from 50 to 100% of the second growth infested with mosaic on old tobacco fields. The amount of infectious material that is present both in the above-ground parts and in the roots, in view

of the high dilution at which the virus will remain infectious, is consequently very great. If it were not for the fact that natural conditions destroy probably 95% of this virus between growing seasons, it would be extremely difficult to grow any tobacco free from mosaic. By the "local-lesion" method it has been found possible to study the behavior of the virus remaining in the soil over winter. As the tobacco refuse dries up, freezes, and decays, much of the virus is leached into the soil itself by rains. Such "free" virus in the soil is, strangely enough, destroyed both by freezing and by drying of the soil. The virus in the refuse remaining above ground is likewise almost completely destroyed by decomposition and weathering. On the other hand, the virus remains alive in considerable concentration in the roots and other refuse if it is plowed under, even though considerable decay of the plant tissues occurs before the following summer. Evidently the soil covering protects the mosaic virus from the injurious action of excessive weathering. In the early spring and summer more virus again leaches out of these protected tissues, and if there is no further freezing or drying, "free" virus may again be found in the soil. Nevertheless by far the greater portion of the virus originally present on and in the soil has been destroyed during the winter period. The weather conditions hence play an important part in determining the amount of virus present. Drying and freezing nevertheless favor survival of the virus in undecomposed refuse because these conditions retard decay. Decomposition is brought about by soil organisms, and conditions favoring their growth hasten the destruction of the virus. The removal of the refuse from the field, even where the main roots are included, does not appear to be either an efficient or a practical control measure, largely because only a part of the infested material can be actually removed in this manner.

When tobacco is planted on infested soils, the percentage of mosaic developing will naturally bear some relation to the amount of virus present in the surface soil. The hands may become contaminated from infested soil and transmit the disease at transplanting time. Infested stubble or roots lying on the soil surface may also be handled by the workers, with further hand contamination and subsequent infection of the young transplants. The plant hairs on the young stems and leaves may also be broken in direct contact with infested soil and thus start infection. At other times, infection from the soil may not occur until days or weeks later, when the leaves are brushed against the soil as a result of a storm or wind. As the surface soil dries out, the danger of infection from this source is reduced.

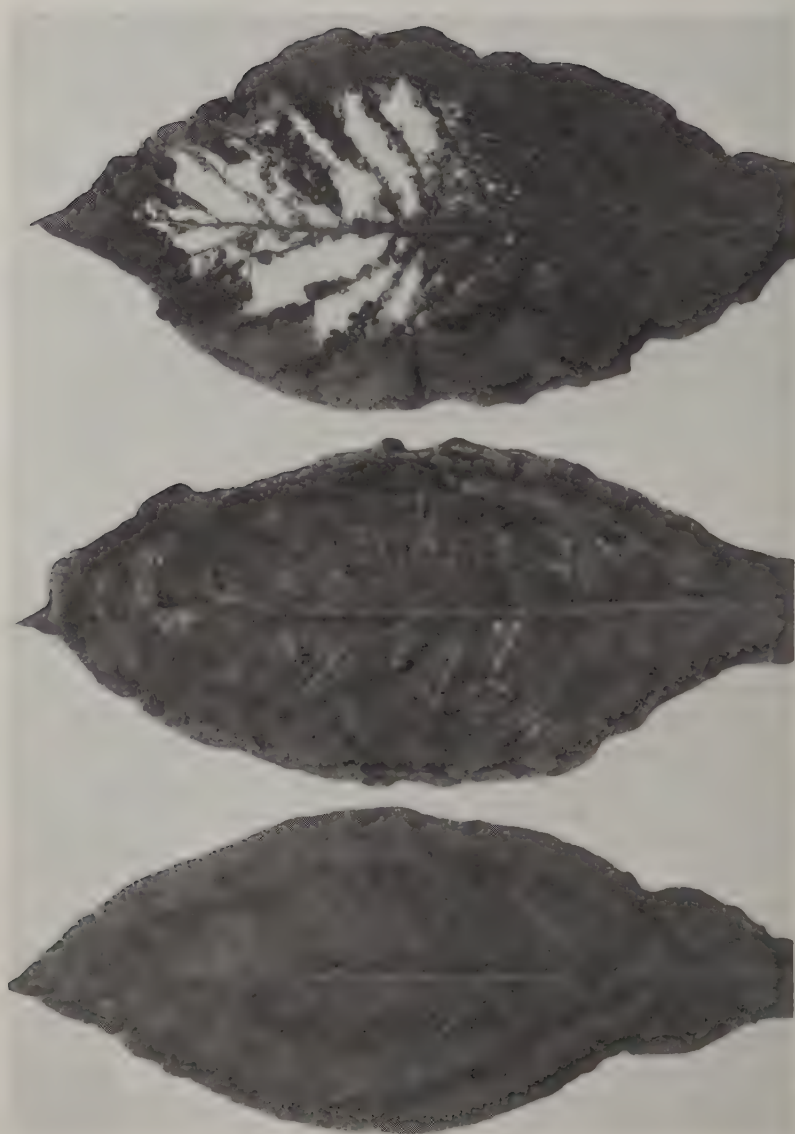


FIG. 4.—ANOTHER EXAMPLE OF MOSAIC RUST SHOWING UNIFORM SPOTTING, SPOTTING ALONG THE VEINS, AND THE RAGGED LEAVES OFTEN RESULTING

In the meantime, however, infested soil may be repeatedly brought to the surface by cultivation. If the season is very dry or storms rare, the percentage of infection may be considerably lower than in wet seasons with frequent or heavy storms, bringing moist infested soil and the leaves in more extensive contact. Field records of mosaic kept over an eleven-year period at this station show distinctly less mosaic in drought years.

Although the continuous culture of tobacco on the same land for many years has many advantages, yield and quality considered, it naturally results in the accumulation of the mosaic virus in the soil. The disease may eventually become so destructive as to outweigh the benefits of continuous culture, making a change of tobacco land necessary or desirable. However, the new tobacco field should be carefully selected, since the injurious effects of certain preceding crops, like timothy, on the yield and quality of tobacco, may reduce the return per acre more than the mosaic did on the old field. Keeping tobacco off the land for one year may remove a large part of the virus from the soil, but under some circumstances it may take two years to entirely eliminate the possibility of infection from this source. If the mosaic-infested land is to be again grown to tobacco, it is often best to plant to corn, potatoes, or other cultivated crops and not to introduce a sod crop, which may result in injurious effects on subsequent tobacco crops. If sod land must be used for tobacco, it is advisable not to plant directly after sod, but to introduce some cultivated crop such as corn in the rotation.

Cured Tobacco Refuse

The refuse from harvested tobacco, cured and stored in buildings, is naturally not subjected to the same rate of decomposition and weathering as that remaining in the field. The virus is essentially preserved indefinitely in cured tobacco refuse so long as it remains dry. Such materials (stalks, trash, sweepings, stems from stemmeries and factories) are often returned to tobacco land for fertilizing purposes. If some judgment is not used in such instances, it may be responsible for considerable mosaic. When this type of refuse is spread on the land and exposed to direct weathering, it may require a period of five or six months depending on weather conditions, for the virus to be destroyed. Plowing under may increase rather than shorten the time required for destruction of the virus. Hence if stalks, etc., can be applied to tobacco land before mid-winter, it is ordinarily safe to use them on tobacco land, but if not, it is better to use them on land not intended for the tobacco crop.

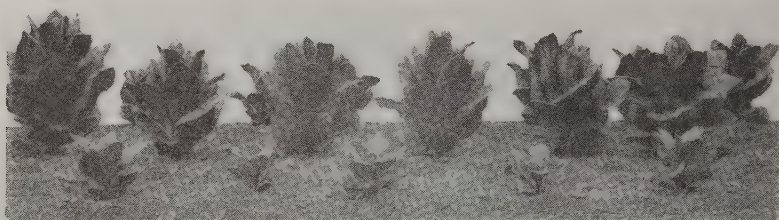


Fig. 5—HEAVY STUNTING OF GROWTH IS A COMMON RESULT OF EARLY INFECTION OF THE PLANTS

These plants were all transplanted at the same time, but the five plants in the foreground were infected with mosaic soon after planting.

Tobacco stems from certain stemmeries do not always contain the mosaic virus, because of the artificial heat used during the preparation and processing of the leaf. Stems from other stemmeries or from cigar factories are not treated in this manner, and hence must be regarded as carrying mosaic. It is especially important that no tobacco refuse of any kind be used as a seed-bed fertilizer, nor applied as an insecticide. The location of seed-beds with respect to any possible accidental source of infection from curing-shed refuse should also be considered. It is no longer considered good practice for the control of any tobacco disease to locate the seed-beds alongside or near the curing sheds. It may also be recalled that seed pods (but not the seed) may carry the virus and consequently the sowing of poorly cleaned seed may introduce sufficient infested refuse to start some infection in the young plants.

Through the Use of Tobacco

In some tobacco districts of the United States it is believed that the use of tobacco by workers when handling the growing plants is the chief source of mosaic infection in the seed-bed and in the field. It is true that some forms of commercial tobacco, as well as the leaf-tobacco sometimes used by growers, may contain the living virus although several years old. Tests at this Station have shown that about 67% of the cigars, 81% of the cigarettes, and 62% of the pipe tobaccos carry the virus in some degree. On the other hand only 30% of random samples of leaf-tobacco carried the virus. The mixing or blending for the commercial brands of tobacco naturally increases the percentage of tobacco infested though the actual virus concentration is lowered. Manufactured chewing tobaccos and snuff apparently contain little or no virus on account of the higher temperatures to which these are exposed in processing or manufacturing.

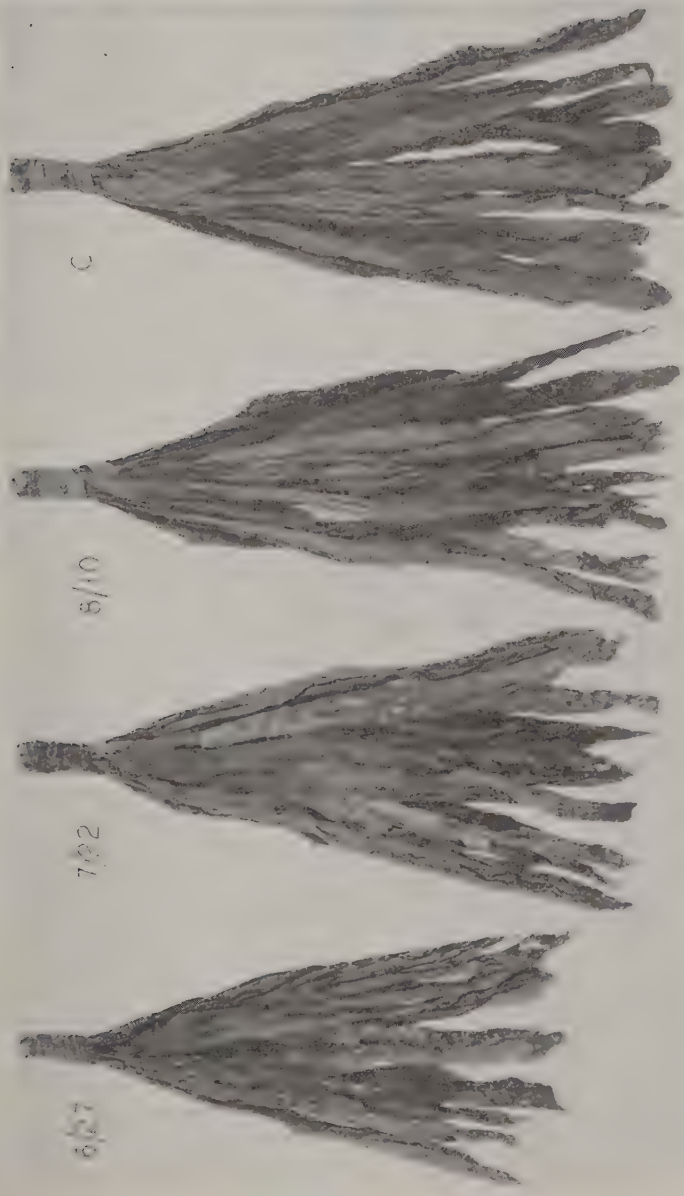


Fig. 6—MOSAIC REDUCES THE YIELD AND QUALITY OF TOBACCO IN PROPORTION TO THE STAGE OF GROWTH AT WHICH THE PLANTS BECAME INFECTED

The figures show the date of infection of plants from which these samples were taken in comparison with healthy plants (c) grown in an adjoining row.

In connection with the relative danger of infection from this source it is necessary to consider the concentration of virus present in these products, and the actual possibilities of the hands being contaminated with the virus when tobacco is used by the workers. The use of "natural" or unmanufactured leaf tobacco by the workers in the crop is most likely to result in infection, because such tobacco may not only contain more virus, but is often handled more carelessly. In some of the Southern tobacco districts of the United States the use of such "natural" leaf-tobacco is regarded as the most important source of infection. Actually, the concentration of virus is relatively low in most manufactured brands, and tests by the "local-lesion" method of study have shown that unless the attempts at infection in this manner are intentional, the percentage of mosaic resulting is very low, as compared to that which may arise from such a source as infested soil. It is nevertheless obvious that the careless use of tobacco, and its disposal in and about seed beds in particular, or during transplanting, may result in a limited amount of infection. This danger may be checked when deemed necessary either by avoiding the use of tobacco at such times, or by using such forms of tobacco as may be adequately sterilized by heat (in "dry" steam or hot air oven, 15 minutes or more).

Other Susceptible Plants

The tomato is about the only other plant commonly grown on the farm which is susceptible to tobacco mosaic. Black night-shade, a closely related plant is a fairly common weed in some sections, but is not commonly infected. Some related perennial weeds such as ground cherry are more likely to carry infection from year to year. The significance of these weeds as sources of infection is dependent to a great extent on the possibilities of insect transmission of the virus to tobacco, a factor which is no longer believed to be of common occurrence in the case of the tobacco mosaic virus, though it is an important factor with the cucumber mosaic virus which sometimes occurs on tobacco.

The mosaic disease on tomato is very common, though often not as conspicuous in its symptoms as on tobacco. Because the disease on tobacco and tomato are caused by the same virus, tomato soils and refuse from tomato crops should be regarded in the same light as tobacco soils and refuse so far as control of mosaic on tobacco is concerned.

Field Infection from the Seed-bed

WHERE HIGH percentages of mosaic are found in the field 10 to 20 days after transplanting, it is most likely that the disease came from infected seed-beds. This is especially noticeable at times when planting in the same field has been made out of seed beds from different farms. Such field infection is, of course, quite as likely to occur on new tobacco land as on old tobacco land. When the percentage of infection in the field from seed-beds is low (below 10%) on new or previously uninfested soil, it is a good policy to remove the diseased plants as early as possible, with the purpose of checking spread to other plants and to reduce subsequent infestation of the soil. In instances where field infection from seed-beds is as high as 25% in the planting season, it may be advantageous to replot and replant with healthy plants.

Where the grower has reason to believe that seed-bed infection is responsible for the field infection, the location of the seed-bed should be changed for the following year and all the suggested precautions taken to avoid such further occurrence. The production of mosaic-free plants in the seed-bed should never be difficult to accomplish, if all sources of infection previously described are eliminated.

It is likely that infection occurring at the time of transplanting may be sometimes mistaken for seed bed infection. Mosaic sometimes runs into large percentages in rows adjacent to healthy rows, or alternate plants in the row may be regularly infected. This situation may in part come about through contamination of the workers' hands as a result of handling old diseased roots or other refuse during the planting operation, the alternate infections being explained by machine planting. Such a field distribution of infected plants may also naturally arise from transplanting infected plants from a small spot in the seed-bed. Unfortunately, it is rarely possible to determine the presence of mosaic in closely crowded plant-beds at transplanting time. The presence or absence of mosaic in the seed-bed may ordinarily be determined by observation two to four weeks after the last planting has been made.

As previously stated, the seed-beds should never be fertilized with tobacco refuse of any kind, and it is also not advisable to locate the seed-beds close to curing sheds or other buildings where tobacco refuse may easily be accidentally blown or otherwise carried into the seed-bed frames. For this reason also, seed-bed frames and cloth covers should not be stored in the curing shed where such equipment may become contaminated with mosaic and other diseases.



Fig. 7--THE "LOCAL-LESION" METHOD OF STUDYING MOSAIC

If an extract is made of any material suspected of harboring the mosaic virus, (such as old roots, soil, refuse, manufactured tobacco, etc.) and wiped over the leaf surface of a special type of tobacco used for this purpose, the number of spots resulting shows the approximate amount of virus present.

Spread in the Field

MOSAIC SPREAD may be considered as the infection which arises directly from living diseased plants, as contrasted to that which originates directly from overwintered sources of infection. The spread of ordinary tobacco mosaic from diseased to healthy plants was at one time believed to be due largely to insects, especially plant lice (aphids). At that time the possibilities of the control of tobacco mosaic appeared to be remote on account of the practical difficulty of completely controlling plant lice. It has now been shown that these insects are not concerned with the spread of ordinary tobacco mosaic from tobacco to tobacco, although aphids may spread the similar but much more rare cucumber mosaic in tobacco fields.

After it was determined that insect spread was practically out of question, it became obvious that the common and important spread was through cultural practices, such as weeding, pulling and transplanting plants, worming, topping, suckering, harvesting, and possibly through cultivation, where man, horse, or equipment brushed alternately against diseased and healthy plants. These cultural operations cannot be eliminated and cannot be easily regulated so as to avoid all unnecessary touching of the plants. If only very low percentages of mosaic occur, as a result of avoiding the important sources of infection, the amount of spread due to working in the crop may be small. If as much as 10% of mosaic has developed by topping time, it may often be practical to exercise some extra precautions in topping to avoid considerable unnecessary spread from this source. This can be accomplished either by one man topping all of the apparently healthy plants before topping the mosaic ones, or two men working at the same time, one topping healthy plants and the other, diseased plants. A further precaution should be taken when the healthy plants are being topped, of occasionally washing the hands with soap and water to remove accidental virus contamination.

It is clear that plants may be infectious before showing clear symptoms of the disease, and that perfect efficiency of any cultural practice aimed at avoiding the spread of mosaic cannot be expected.

It is in relation to mosaic spread that the practical value of the early removal (roguing) of the mosaic plants suggests itself. As previously stated, it is likely that such a control measure when applied on uninfested soils to low percentages of mosaic plants, obviously infected before or at the time of transplanting, may greatly reduce subsequent spread. Attempts to check mosaic by roguing where as much as 5% of the plants are infected

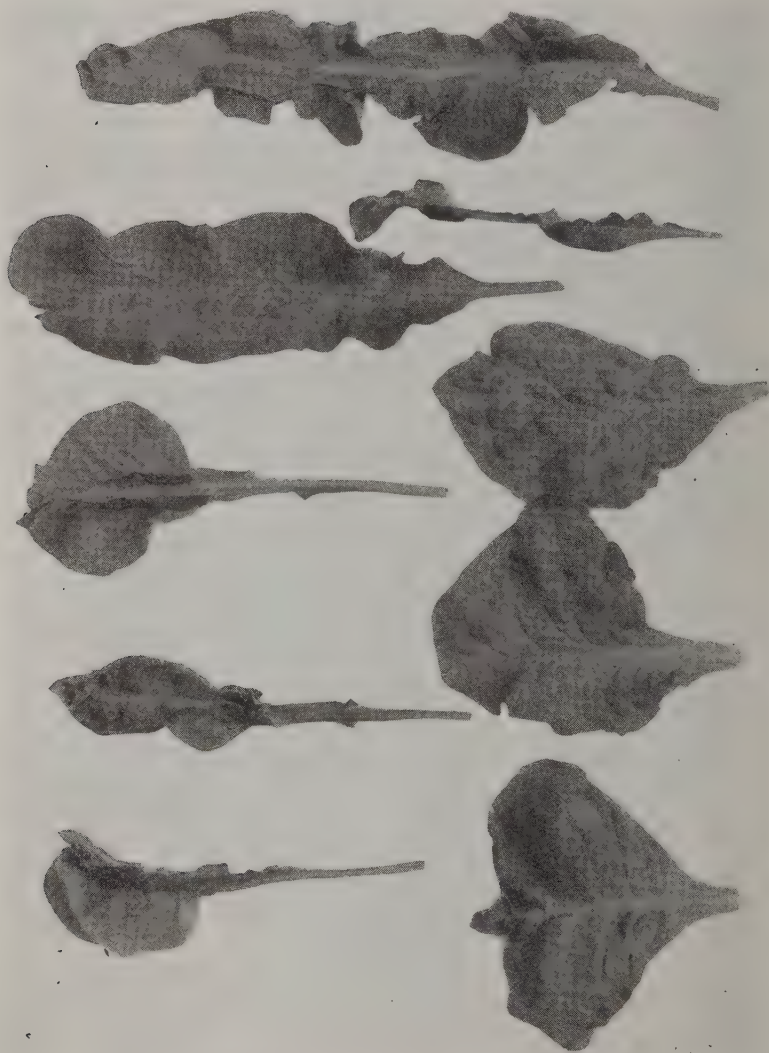


Fig. 8—MOSAIC SOMETIMES RESULTS IN ODD LEAF SHAPES

early in the season and the planting is on mosaic infested soil are not recommended.

Another means of natural spread of mosaic which may be more common than is generally supposed is that due to the contact of diseased plants with healthy plants, particularly during wind or rain storms. The wounds from such contacts may be only broken leaf hairs and invisible in size, but sufficient for infection to occur when the virus is present at the point of wounding. That such infection may occur has been demonstrated experimentally. Its significance under practical conditions is proportional to the percentage and distribution of previously diseased plants in the field, and the size of the plants at the time the winds or storms occur. Although this is an unpreventable form of spread, it emphasizes the fact that the only logical means of control of mosaic now available is that of checking the percentage of infection originating from the possible sources of infection mentioned.

Mosaic-resistant Varieties

ALL COMMON commercial varieties and strains of tobacco grown in the United States and in most other countries are equally susceptible to mosaic. A few years ago a variety of tobacco (Ambalema) was found in South America which possesses considerable natural resistance to tobacco mosaic and more recently other resistant varieties have been found in that country. Although these types are of no commercial value in this country, attempts are now being made to introduce the mosaic-resistant character of these varieties into commercial American strains. While some progress has been made, it is yet too early to predict what the final results may be. In any case it will require a considerable number of years to develop and to test out the most promising new strains commercially. The obvious advantage of disease-resistant commercial strains over other more complicated disease control methods is well known.

Summary of Control Measures

1. The control of tobacco mosaic depends on preventing the plants in the seed-bed and field from becoming contaminated with diseased material from previous crops. This source of infection may be one or more of the following: (A) infested soil and field refuse; (B) refuse from harvested tobacco; (C) manufactured and "natural" leaf tobacco used by the workers in the crop; (D) certain other plants susceptible to the disease, especially tomato.

2. Infested soils, that is, fields on which tobacco infected with mosaic was grown the preceding year is regarded as the most common and important source of infection in Wisconsin. If the percentage of mosaic in a field is high, and other suitable soil for tobacco is available, a change of tobacco land is advisable.

3. Refuse from harvested tobacco, that is stalks, trash and stems should not be used as a seed-bed fertilizer or insecticide. Only seed free from chaff should be sown in the seed-bed. Neither is it advisable to apply tobacco refuse as a field fertilizer unless allowed to weather and decay on the land five to six months prior to planting to tobacco. Plowing under of refuse is of no value in hastening the destruction of the virus.

4. There is some danger of seed-bed and field plants becoming infected through workers using certain forms of tobacco, especially unmanufactured or leaf-tobacco.

5. As far as tobacco mosaic control is concerned, tomato crops or refuse from such crops should be regarded as a likely source of infection.

6. Seed-beds should not be located near tobacco sheds, because of the danger of accidental contamination. Seed-bed frames and covers or tools used, if stored in tobacco sheds are likely to carry some diseased material to the seed-beds.

7. The removal (roguing) of low percentages of diseased plants from the field early in the season is recommended on soil not grown to tobacco for two or more years, but roguing is not practical on old mosaic-infested tobacco land.

8. The use of some precautions in handling diseased and healthy plants separately during such work as hoeing, worming, and especially in topping tobacco may greatly reduce the spread of the disease in the field.

9. The kind and amount of precaution necessary to control mosaic varies greatly with circumstances on individual farms and with the individual growers. The grower should therefore understand the disease, the sources of infection, and the manner in which it spreads, and then give attention to such preventive measures as may apply to his particular situation.

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LEITH, B. D., Agronomy
LEOPOLD, A., Wildlife Management
LINK, K. P., Biochemistry
MC COY, ELIZABETH, Agr. Bacteriology
MC NALL, P. E., Agr. Economics
MILWARD, J. G., Horticulture
MITCHELL, D. R., Agr. Economics
MOORE, J. G., Chairman of Horticulture
MORTENSON, W. P., Agr. Economics
NEAL, N. P., Agronomy & Genetics
PARSONS, HELEN T., Home Economics
PARSONS, K. H., Agr. Economics (Leave of Absence Acad. Yr. 1939-40)
PETERSON, W. H., Biochemistry
PHILLIPS, P. H., Biochemistry
PRICE, W. V., Dairy Industry
RIEMAN, G. H., Genetics, Horticulture, & Plant Pathology
RIKER, A. J., Plant Pathology
ROBERTS, R. H., Horticulture
ROCHE, B. H., Animal Husbandry
RUPEL, I. W., Dairy Husbandry
SARLES, W. B., Agr. Bacteriology
SCHAARS, M. A., Agr. Economics
SEARLS, E. M., Econ. Entomology
SHANDS, H. L., Agronomy
*SHANDS, R. G., Agronomy
*SMITH, W. K., Agronomy & Genetics
SOMMER, H. H., Dairy Industry
STEENBOCK, H., Biochemistry
STRONG, F. M., Biochemistry
THOMSEN, L. C., Dairy Industry
TOTTINGHAM, W. E., Biochemistry
TRUOG, E., Chairman of Soils
*WALKER, J. C., Plant Pathology
WECKEL, K. G., Dairy Industry
WEHRWEIN, G. S., Agr. Economics
WHITSON, A. R., Soils
*WILDE, S. A., Soils
WILEDEN, A. F., Rural Sociology
WILSON, H. F., Chairman of Econ. Entomology
WILSON, P. W., Agr. Bacteriology & Biochemistry
WISNICKY, W., Veterinary Science
WITZEL, S. A., Agr. Engineering
*WRIGHT, A. H., Agronomy
*ZON, R., Forestry (St. Paul)
ZUILL, FRANCES L., Chairman of Home Economics

BRUHN, H. D., Agr. Engineering
*CALLENBACH, J. A., Econ. Entomology
COMBS, O. B., Horticulture
DICKERSON, G. E., Dairy Husbandry & Genetics
EISENHART, C., Station Statistician
*FERGUSON, L. C., Veterinary Science
*FEUTZ, F., Dairy Industry (Monroe)
HOVELAND, N. H., Administration
JOHNSON, M. J., Biochemistry
LARSON, R. H., Plant Pathology
LILLY, J. H., Econ. Entomology

MC CARTER, JANET, Agr. Bacteriology
MUCKENHIRN, R. J., Soils
NUSBAUM, D. D., Dairy Industry
OGDEN, W. B., Horticulture
PLATZ, MRS. BLANCHE M., Biochemistry
*POUNDEN, W. D., Veterinary Science
*SCHAEFER, C. W., Econ. Entomology
STROMMEN, A. M., Agronomy & Branch Stations (Spooner)
UMBREIT, W. W., Agr. Bacteriology
WEHRWEIN, C. F., Agr. Economics
WHITPLE, O. C., Plant Pathology

*Jointly employed by the Wisconsin Agricultural Experiment Station and the U. S. Dept. of Agriculture.

